# Cranial Nerves

## Preface

Before we begin, we'd like to offer up a thought exercise, one that challenges the conventional instruction of the cranial nerves. Consider learning all of the peripheral nerves at once, without context. Just all of them lumped together in a table, in order from top to bottom. You are asked to memorize what they innervate, and also how they combine into terminal nerve roots. Sound effective? No. How about this: build a table of insertion points, attachment points, function, innervation, and vascular supply to learn all the muscles of the body. No, wait—it must be arbitrary, so do it in alphabetical order. Sound effective? You obviously wouldn't do that. So, it perplexes us that the tradition of teaching the cranial nerves in an arbitrary way—in numerical order, numbered in order by how far cranial or caudal they emerge from the brain or brainstem (that's how they get their number, site of emergence, from the most cranial to most caudal)—seems to be the only way to do it.

Just because there are fewer cranial nerves than peripheral nerves or muscles doesn't mean it makes any more sense to do it in an arbitrary order without any consideration of their function. So, we don't do it that way. This lesson is not a litany of the names, functions, and dysfunctions of the cranial nerves. This lesson is about learning what cranial nerves are and maximizing your comprehension of the brainstem from the perspective of the nerves. When appropriate, we'll use an example cranial nerve to illustrate a point. You'll get snippets of all the cranial nerves except for the facial nerve (motor to the face) and the trigeminal nerve (sensory to the face), which we will explore in full detail. The others are going to be discussed where they are appropriate—the Special Senses island in Neuroscience; in Gastroenterology, where the glossopharyngeal, vagus, and hypoglossal nerves coordinate swallowing; and really in every organ system, because the vagus nerve is the parasympathetic nerve for most of the viscera in the abdomen and pelvis, or the vestibulocochlear nerve that is involved in audition and balance. Notice, so far, no Roman numerals. It doesn't help you to know the vagus nerve is the tenth cranial nerve, or that X is 10 in Latin. It matters more that you know that it's the really long one that drives parasympathetic tone to the entirety of the viscera. You will get the Roman numerals so that you are acquainted with how the cranial nerves are handled by everyone else. We strive for you to master the concept, not memorize a table. Don't study cranial nerves 1–12 (or *I per XII*)—study the cranial nerve involved in the health and disease of the organs with which it is associated.

## Introduction

Cranial nerves are the peripheral nerves of the cranium. Neurons of the same tract develop in nuclei, separate from the neurons and nuclei of other systems. The axons of those nuclei travel together in fascicles and are from the same tract, separate from the axons of other tracts. Peripheral nerves of the spinal cord carry all the sensory (afferent) and motor (efferent) fibers from all systems out into the periphery of their dermatome. Nerve roots contain every tract found in the spinal cord. Nerve roots combine to become terminal nerve fibers that innervate organs and skin. That means that in the periphery, each tract mixes and mashes with the same tract of multiple spinal levels, and every tract is represented in a peripheral nerve. That's why you get all those little fibers coming off the posterior and anterior horns and one big nerve leaving the vertebral column.

Cranial nerves are the peripheral nerves of the cranium, except significantly simpler. The cranium and brainstem have the luxury of being contained within the skull. You can think of the brainstem as its own vertebral level—every system (sensory, motor, sympathetic, parasympathetic, brainstem, cortex, etc.) must be represented, but instead of bundling all of those axons into one nerve root, the brainstem divides those responsibilities between multiple cranial nerves. In addition, there are **special senses**—smell, taste, vision, audition, and balance—each handled by a different cranial nerve or set of cranial nerves. The motor homunculus and sensory homunculus showed us that the most neurons are dedicated to the face and hands. You can expect, then, with many neurons serving fine motor control and many neurons dedicated to the sensation of the face, that there are going to be just as many axons for those neurons, necessitating larger nerves.

Because the cranial nerves, together as a unit, provide every tract to the skull and face, and because each function is handled by one nerve, the **more neurons are dedicated to a function**, the **more axons there will be**, and therefore, the **larger the nerve will be**. Some nerves may be **purely motor**, some nerves may be **purely sensory**, but most nerves are **mixed nerves**. They can carry autonomic fibers, somatic fibers, or both. If they carry more than one function, they must be derived from multiple nuclei. And because neurons in the CNS only hang out with other neurons of their tract, any cranial nerve that has mixed function must be made up of **combined axons from multiple tracts**. Thus, for most cranial nerves, there are no originating nuclei. Like peripheral nerves, they are the combination of axons from multiple tracts; however, these nerves don't combine those tracts outside the brainstem, as the peripheral nerves do in the spine. Instead, they merely **emerge from the anterior brainstem** as the already formed nerve. In the periphery, nerves can mix and match, just as peripheral nerves do, to form terminal branches.

The brainstem nuclei are connected to the cortex. Cortical motor neurons are connected to their corresponding motor nuclei through the **corticobulbar tract** (the equivalent of the corticospinal tract), and sensory nerves synapse on the thalamus before climbing to the sensory cortex. Sensory tracts are equivalent to the spinothalamic tract and the DCMLS. They decussate at the level of their synapse. In this way it isn't just that cranial nerves are the peripheral nerves of the cranium, it is as if the cranial nerves share a "vertebral level" (brainstem) and share the burden of a massively important, high-neuron, high-axon burden organ (the face and mouth), not to mention the additional burden of vision, audition, balance, olfaction, and taste. Just as all tracts converge to leave the spinal cord for that peripheral nerve to service all innervations of the dermatome they are assigned, all already "converged" in the cranium.

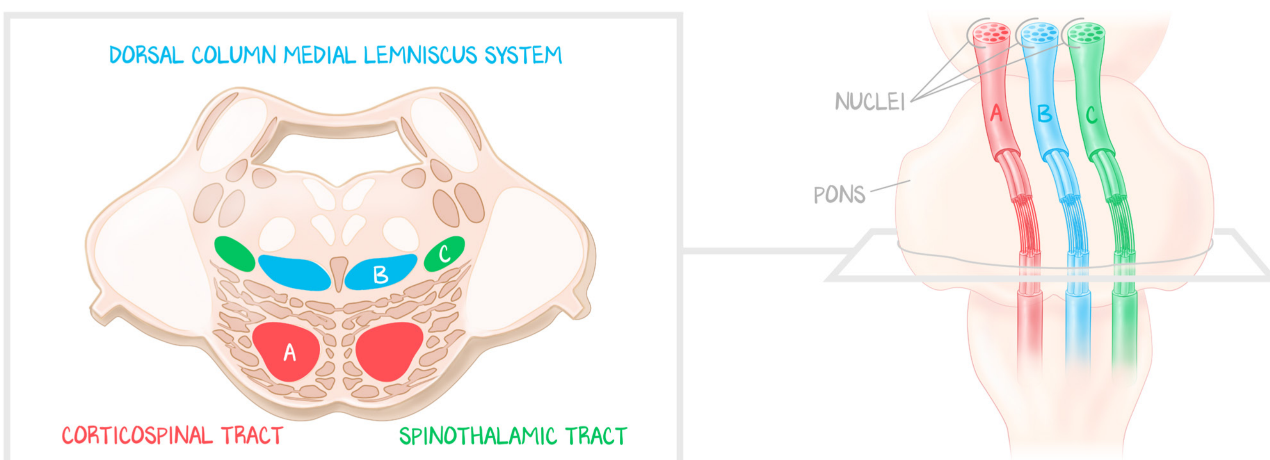


**Figure 5.1: Nuclei and Fascicles Don't Mix in the CNS**
The central nervous system develops through the replication of cells, just like any other organ. But unlike other organs, the central nervous system uses electricity—action potentials—to send and receive information over great distances. The action potentials are fast, but to take advantage of electricity as a form of communication, the wires must already be there. That is, the axons are already in place, and always have been, getting longer as a child grows. Because the cell bodies of like-minded neurons are derived from a common precursor, replication during development necessitates that the clusters of neurons—nuclei—remain clustered together. The same is true of their axons. We can easily follow a tract and know where the axons are in a fascicle (DCMLS, corticospinal tract, medullary pyramids) because the axons of common systems run together. The only way you can get a nerve to carry multiple functions is to contain axons of different tracts, and only peripheral nerves do that.

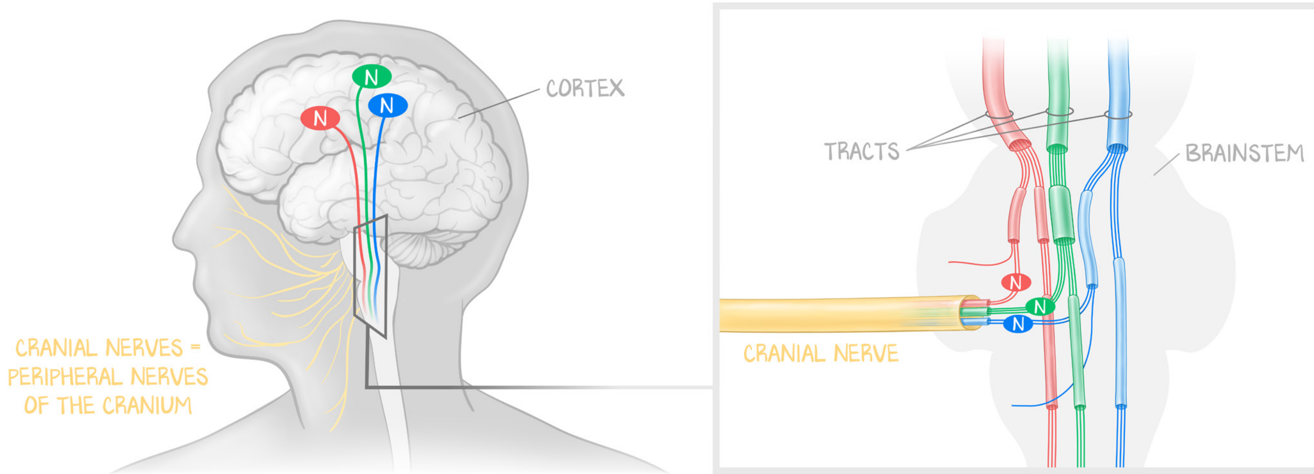


**Figure 5.2: Cranial Nerves Are Peripheral Nerves of the Cranium**
Because cranial nerves may carry more than one tract, and tracts run in fascicles of their own kind, those different fascicles must be contained in a larger nerve. Cranial nerves are not just like peripheral nerves because peripheral nerves must carry all motor and sensory axons for the periphery, whereas cranial nerves bring all motor and sensory to the face, but split the work between them.

You can predict which cranial nerves will arise medially, laterally, or in between. Remember, from embryology, that there is an alar plate (sensory, dorsal, posterior) and a basal plate (motor, ventral, anterior), separated by the canal that will become the CSF space? That worked out really well in the spinal cord. The brainstem develops the same way, with an alar plate, a basal plate, and a sulcus limitans. Only, in the brainstem, there isn't a tiny spinal canal, instead there are massive **ventricles and aqueducts**. What happens in development is that the ventricles develop in the back (dorsal, posterior) and widen from behind. This leaves the basal plate (motor, ventral, anterior) where it was, and forces the alar plate (sensory, dorsal, posterior) out around the sides, enveloping the basal plate. No longer is it anterior-posterior, but rather **motor is medial** and **sensory is lateral**. Those cranial nerves that are **purely sensory** will emerge from the brainstem the **most laterally**. Those cranial nerves that are **purely motor** will emerge from the brainstem the **most medially**. Any of them that are **combined** will be **in between**, usually on the more lateral side.

A simple example is CN III, the oculomotor nerve. The oculomotor nerve is made up of axons from nuclei that control some of the extrinsic muscles of the eye (four of the six) and axons of neurons that are responsible for the parasympathetic output to the pupil. It is derived from two nuclei, one for each of its functions. Since both are purely motor, the two nuclei are found medially. Because it is a lower-numbered cranial nerve, those nuclei are likely to be higher up in the brainstem. Indeed, they are.

The last thing before we get started—nerves don't depolarize, fascicles don't depolarize, but **neurons depolarize**, and their **axons depolarize**. The Edinger-Westphal nucleus is the parasympathetic innervation to the pupil, and the oculomotor nucleus is the somatic skeletal muscle innervation. The pupil can constrict (some EW neurons depolarize) without obliterating the pupil (as would be the case if the nucleus—all the neurons—depolarized at once) and without moving the eye (the oculomotor neurons depolarize independently of the nucleus and the nerve).

 

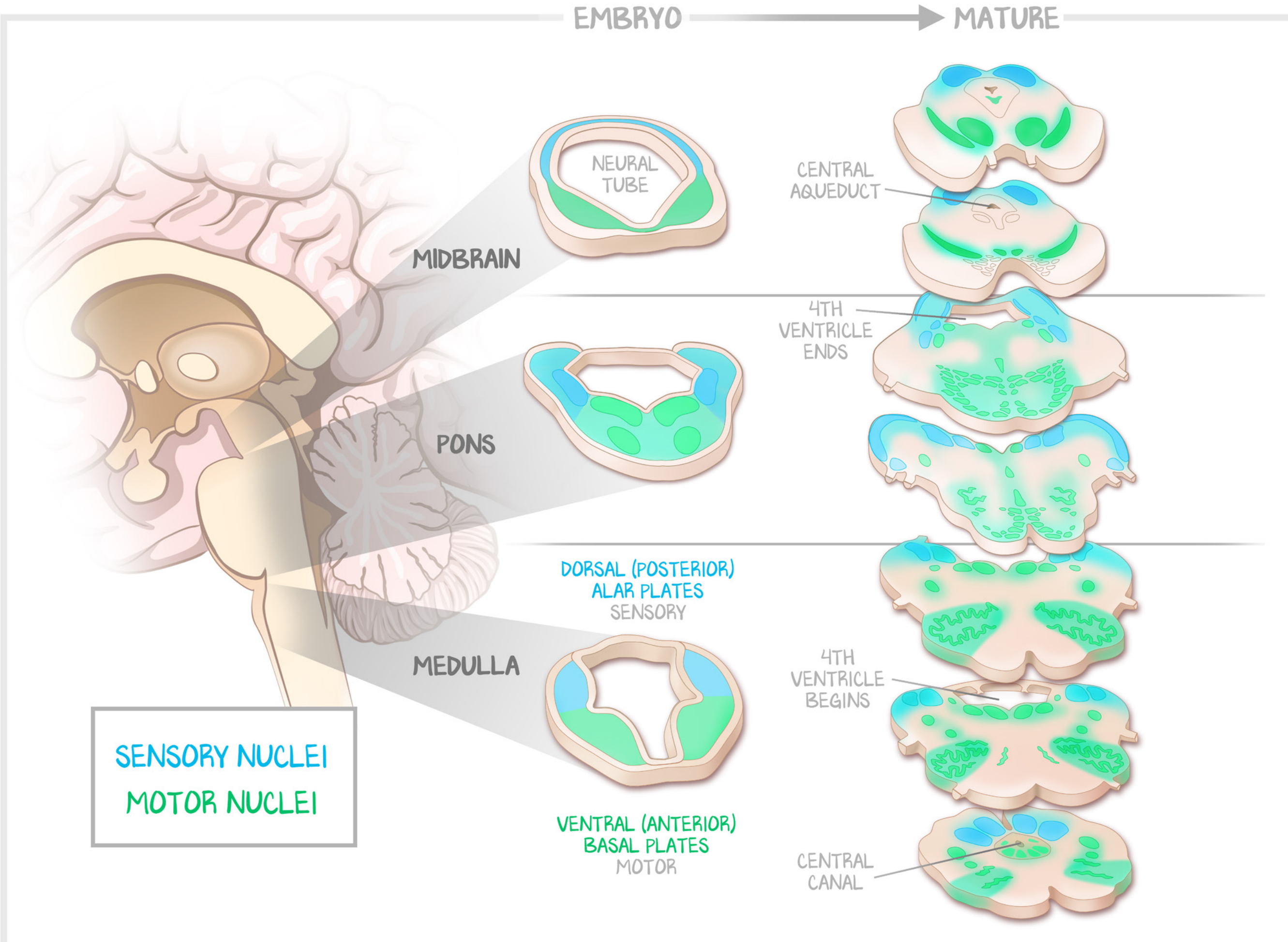


**Figure 5.3: The Ventricles Push the Sensory Nuclei Around**
A reminder from the first lesson because what you learned then is valuable now. The alar plate is posterior and houses sensory nuclei, whereas the basal plate is anterior and houses motor neurons. Where there are ventricles, the ventricles "open" the posterior of the brainstem, pushing sensory nuclei around the sides of the motor nuclei. Although the tracts—axons—can be wherever they want, but the location of the nuclei remains consistent—sensory posterior when closed, lateral when open, motor anterior and medial.

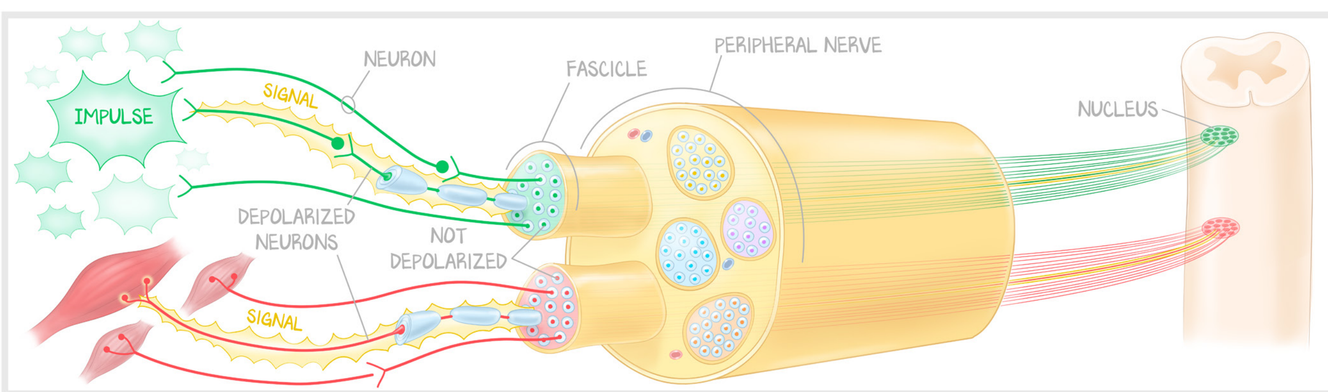


**Figure 5.4: Nerves Don't Depolarize, Axons Do**
Each neuron has an axon, and that axon, like the cell body itself, conducts action potentials. Axons are separated from one another within fascicles by myelin (Schwann cells) and satellite cells. Fascicles are kept separate, so only axons of a tract are in a fascicle together. The electrical signal (the conduction of an action potential) only causes membrane voltage changes in the axon it is traveling in or the neuron it will synapse upon. The sheer number of axons, each either depolarizing or not depolarizing, gives the central nervous system a nearly infinite number of states.

 

## The Obligatory Cranial Nerve Table—FOR REFERENCE ONLY

Do not memorize this table. This is here for you to look back at as you progress through the text.

| LOCATION | CN | NERVE | FUNCTION | TYPE |
|---|---|---|---|---|
| Above or Midbrain | I | Olfactory | Smell (only one that bypasses thalamus) | Sensory |
| | II | Optic | Vision (optic chiasm) | Sensory |
| | III | Oculomotor | Parasympathetics to pupil, skeletal muscle of four extraocular muscles: inferior rectus, superior rectus, medial rectus, and inferior oblique | Motor |
| | IV | Trochlear | Trochlea (pully) and superior oblique | Motor |
| Pons | V | Trigeminal | $V_1$—Cutaneous innervation of the forehead, bridge of nose, eyelids<br>$V_2$—Cutaneous innervation of what the other two don't<br>$V_3$—Cutaneous innervation of the mandible, lower lip, lower half of cheek, and temples<br>Motor—masseter, temporalis, pterygoids | Both |
| | VI | Abducens | Motor to lateral rectus (lateral muscle past midline) | Motor |
| | VII | Facial | Motor to facial muscles and some of swallowing | Both |
| | VIII | Vestibulocochlear | Hearing and balance | Sensory |
| Medulla | IX | Glossopharyngeal | Taste posterior of the tongue, autonomic sensory and motor<br>For the pharynx | Both |
| | X | Vagus | A whole bunch of stuff. Carries message to the medulla, carries the signal from the medulla, including respiratory, cardiac, bowel, pulmonary, renal, etc. All visceral autonomics of the parasympathetic system are carried in the vagus. Also peristalsis and swallowing | Both |
| | XI | Accessory | Is how you can shrug shoulders and turn your head. Boring. And it doesn't even have a nucleus. It is really "CO." | Motor |
| | XII | Hypoglossal | Intrinsic and extrinsic muscles of the tongue | Motor |

**Table 5.1: Cranial Nerves**

## Cranial Nerve Nuclei Maps

This section shows you the brainstem nuclei maps. Through very rigorous research over many decades, the different regions of the brainstem have been mapped to their functions. This is where the idea that nucleus = cranial nerve came from. Sometimes, it is spot on. Sometimes, it just adds to the confusion. We're going to explain it, showing you what you can use from it, and what you cannot.

Small nerves do one function in a very little space and can originate from one nucleus. Those that do are the **trochlear** nerve (CN IV) and the **abducens** nerve (CN VI). They both innervate a single extraocular muscle of the eye. They work with the oculomotor nerve (CN III) to give full control over the motion of eyeball. They are distinct nerves, take their own course, and are covered in epineurium of their own. But the three nerves together are responsible for constricting the pupil and moving the globe. All three are **motor only**, and so are **medial**. The oculomotor nerve carries motor function to the skeletal muscle (oculomotor nucleus) and motor function for the parasympathetics (Edinger-Westphal to the ciliary nucleus, nucleus to the pupil). You can see those in the midline on the map below. You'll also notice that the nuclei of CN III and the nucleus of CN IV are higher up on the brainstem than that of CN VI. That is because the cranial nerves were numbered based on where they emerge from the brainstem, starting with the most rostral (towards the head in development, superior in a standing adult).

The map is drawn showing one half of the puzzle, so as not to crowd the illustration. What is present on the right is present on the left, but only half have been identified on each side. Notice "trigeminal" is listed twice—once as a tiny motor nucleus, once as a gargantuan sensory column along the medial aspect of the midbrain, pons, and medulla. What do you think the **trigeminal nerve does**? Sensation, sensation, sensation, and a little bit of motor. As we discuss below, it is responsible for innervating the sensation of the face, mouth, and tongue. And we taught you in Sensory Systems that the homunculus was largest—had the greatest number of dedicated sensory neurons—at the face. This column is indicative of how many cranial nerve neurons are dedicated to face sensation. And that is a direct reflection of how many axons are in the fascicles of the central nervous tracts, which is a reflection of how many cortical neurons are dedicated to the sensation of the face. The nerve is enormous and divides into three branches in order to get out of the skull and into the skin. One more question: how laterally do you think the trigeminal nerve originates? Certainly, more lateral than medial. Either by the logic that it is mostly sensory and sensory is lateral, or just averaging the weight of the massive column of sensory with the teeny tiny motor nucleus.

Cranial nerve VIII, the **vestibulocochlear nerve**, is a pure sensory nerve. It connects the vestibular system (balance) and the bones of audition (hearing) to the brain. Being the most sensory, it arises the most laterally.

The last one we're going to discuss is the **hypoglossal nerve**. It is cranial nerve XII, so it is the most inferior on the map. It is in the middle because it is purely motor. And having so many muscles in the mouth, it is not surprising to find its nuclear territory so large. It also has a pretty significant territory dedicated to it. The hypoglossal muscle controls the intrinsic muscles of the tongue and all the extrinsic muscles of the tongue that coordinate swallowing. Even if you haven't studied GI yet, certainly this map helps you appreciate how complicated swallowing is going to be—so many neurons to coordinate, so many different contractions.

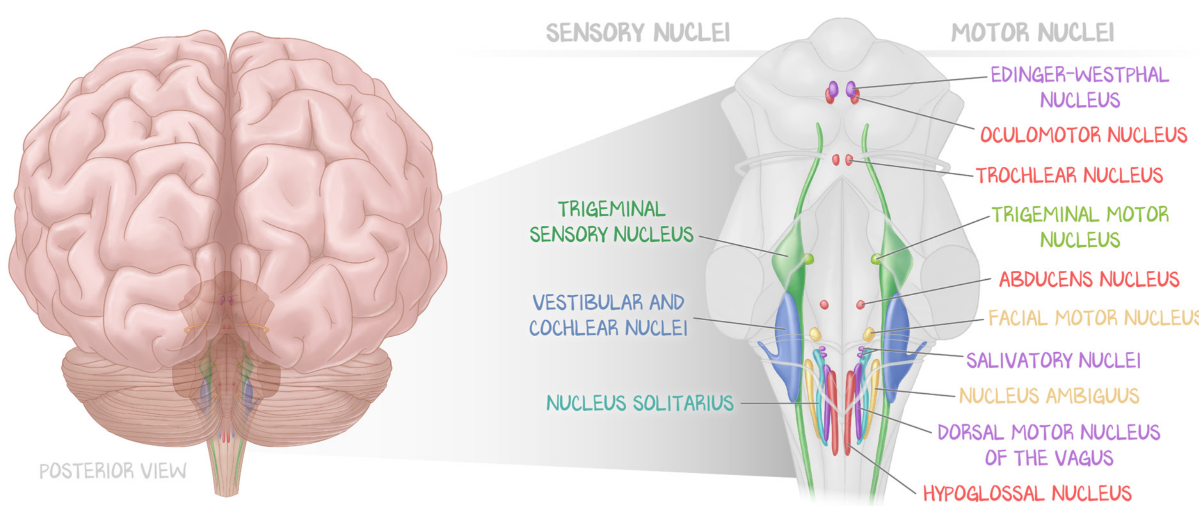


**Figure 5.5: Map of the Cranial Nuclei**
The most you can take away from this illustration is how much sensory the trigeminal nerve is responsible for—lateral and a lot of green—and how dedicated to motor the oculomotor, trochlear, abducens, and most of all hypoglossal (given the size of its nucleus) nerves are—each being very medial.

The medulla is responsible for respiratory rate, blood pressure, initiation of emesis, and emanation of cranial nerves IX, X, XI, and XII. The hypoglossal "nucleus" (really, a tract of nuclei) is present. But, uh . . . where are cranial nerves IX, X, and XI? Well, it turns out that cranial nerve XI (the accessory nerve) is more of a peripheral nerve formed from multiple nerve roots, and is not really a cranial nerve at all (it arises in the cranium, so it *is* a cranial nerve, but it doesn't have a nucleus, so it *isn't* a cranial nerve . . . so it's the sneaky one). Where's cranial nerve I? How about all the autonomics? And here is the thing about this map. It is real, but it doesn't do what learners expect it to—it does NOT define the origin of many of the cranial nerves. Cranial nerve IX (glossopharyngeal) and cranial nerve X (vagus) have so many functions (taste sensation, parasympathetic sensory, parasympathetic motor, sympathetic sensory, and sympathetic motor, to name a few) that they must draw from many nuclei, so cannot be defined by a nucleus or a tract of nuclei.

So, what we learned here is that **when** the origin of a nerve is known by its nuclei, we can use that information with vigor. You should know where the nuclei for the oculomotor (CN III), trochlear (CN IV), and abducens (CN VI) nerves are. You should be able to find the tract of nuclei that make up the hypoglossal (CN XII) "nucleus," the tract of nuclei that make up the vestibulocochlear nerve (CN VIII), and know where the trigeminal nerve (CN V) nuclei (motor and sensation) are. That may seem like a silly hodge-podge with no way to bridge them. Don't try to find a pattern in the numbers. The pattern is in the ratio of nucleus size to the amount of function and the fact that they can be defined when others cannot. You shouldn't try to remember the list of cranial nerve numbers; you should be able to use what you know about their function (size and laterality) and how high in the brainstem they are to deduce which cranial nerve fits the bill.

## Cranial Nerves Made Easier

Because students and faculty alike insist on learning/teaching all twelve nerves at once, we're giving in (a little) to show you how to better manage the list. It's like we're only talking about the nerves where they belong by the way we create the visual organizer. Just remember, "*CN VI is out of place, and CN XI doesn't count.*"

First, where they originate can be recalled as the "Rule of 4's." **Four** cranial nerves originate above the pons (midbrain and above), and they are the first four: CN I, II, III, and IV. **Four** cranial nerves originate at the pons, and they are the second four: CN V, VI, VII, VIII. **Four** cranial nerves originate below the pons (medulla), and they are the last four: CN IX, X, XI, XII. All originate laterally, except for the **four that are purely motor**, which are eye, eye, eye (CN III, IV, VI), and tongue (XII).

Second, link these three sets of four by their general functions. Where they originate helps tell you where they go—superior nerves go to the eyes and nose, pontine nerves go to the face and ears, and inferior nerves go to the mouth and down. CN VI is out of place. It should be midbrain and above because it innervates an eye muscle. CN XI doesn't count because it shrugs the shoulders (and is actually more akin to cervical nerve root zero than a cranial nerve).

**Midbrain goes to the eyes and nose.** CN I is always by itself; it is responsible for smell, and we're going to talk about it during the Special Senses island. So now, the **midbrain goes to the eyes**. Vision is handled by the optic nerve (CN II) and the optic chiasm, which runs near the superior colliculi (which facilitate moving the eyes towards a stimulus that needs attention). The oculomotor nerve (CN III) controls the autonomic motor function of the pupil and motor function of most of the extraocular muscles. The trochlear nerve (CN IV) moves one of the other extraocular muscles of the eye. The eye is incomplete and needs cranial nerve VI, but the midbrain is all about vision and eye movement.

**Pons goes to the face.** The trigeminal nerve (CN V) handles motor function, sensation, and taste of the face. It is very complicated, and we'll go into detail below, but now we're just building the advanced organizer. Abducens (CN VI) finishes the motor to the eyes. The facial nerve (CN VII) handles most of the motor function to the facial muscles and a little bit of sensation. The vestibulocochlear (CN VIII) controls hearing and balance (the ears).

**Medulla goes to mouth and everything below.** Both the glossopharyngeal nerve (CN IX) and the vagus nerve (CN X) are responsible for the taste sensation and the swallowing reflex, and the vagus handles both sensory and motor function for the parasympathetic autonomics in essentially all of the viscera. CN XI is pure motor—skeletal muscle of the sternocleidomastoid and trapezius. If it is a cranial nerve and it is motor, it should originate medially. But in reality, it is effectively a cervical nerve root without the cervical vertebrae. The hypoglossal nerve (CN XII) controls all of the muscles of the tongue.

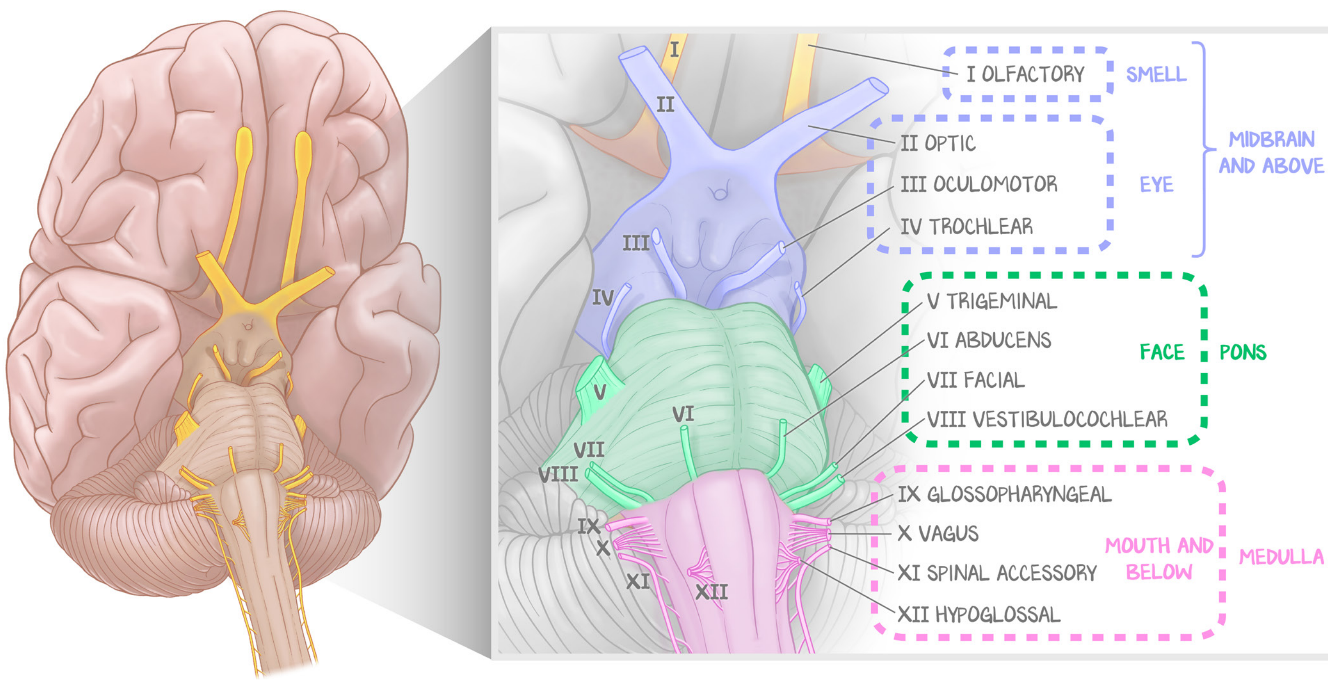


**Figure 5.6: Functional Division of Cranial Nerves and Brainstem Regions**
CN I through CN IV are midbrain and above, and they primarily innervate the eye (by the way, CN I handles smell). CN V through CN VIII are pons, and they innervate the face . . . and ears . . . and . . . a little eye. CN IX through CN XII innervate the mouth and below. This rule of 4's is not the best organizer, but it tends to work. Also, notice where the fibers exit. The pontine cranial nerves (except for CN V) exit below the pons because the cerebellar tracts wrap around the front of the pons (are the front of the pons). Notice how it moves laterally—CN VI, VII, VIII—then comes back medially—CN IX, X, XII—and CN XI doesn't count.

Finally, notice their location. Only the trigeminal nerve (CN V) comes out *within* the pons. The pons is so large because of the cerebellar tracts. It's easier for the cranial nerves to emerge above: the oculomotor nerve (CN III)—or below: abducens (CN VI), facial (CN VII), vestibulocochlear (CN VIII). Also identify the fan pattern—from the medial side in numbered order out to the lateral side: abducens (CN VI), facial (CN VII), vestibulocochlear (VIII)—then from lateral to medial, in numbered order: glossopharyngeal (IX), vagus (X), XI doesn't count, hypoglossal nerve (XII).

 

## Cranial Fossae

The cranial fossae are boundaries established by anatomic limits and the location of parenchyma. There is an anterior, middle, and posterior fossa. These fossae have openings (foramen, canal, fissue, meatus, etc) through which blood vessels, lymphatics, and nerves pass—arteries entering while nerves, veins, and lymphatics exiting.

It is easiest to start at  the bottom and work our way up, as the anatomic barrier is more obvious, and is based on a separation you already know. The cerebral falx splits into the tentorium cerebelli, which take a curving route along side the deep nuclei and complete their course by instering onto the petrous portion of the temporal bone. The temporal bone is the bone on the side of the your head. But it also forms part of the bottom of the skull, and projects a bony ridge into the cranium. Each one does that on either side. Because the tentorium cerebelli insert on the top of the petrous portion of the temporal bone, to be posterior to the petrous part of the temporal bone is to be **under the tentorium.** The **posterior fossa** is **everything from foramen magnum to tentorium.** The occipital lobe, the most posterior nervous structure in the cranium, because it is above the tentorium, is NOT in the posterior fossa, but rather in the middle fossa.

The **middle fossa** is defined by everything **above the tentorium** and **posterior to the wings of the sphenoid**. Posterior to the center of the sphenoid bone is many complicated structures come together—the optic chiasm, pituitary glands, cavernous sinuses, the circle of Willis, midbrain, etc. But the sides of the sphenoid bone, the wings, not much happens at all. Except there is a recess beneath the sphenoid bone, under the wing, where the temporal lobe belongs. Above the sphenoid bone, over the wings, is where the frontal lobes belong. Again, an anatomic separation of brain tissue—this time by bone, last time by dura—is what creates the anatomic barrier between the middle and anterior fossa. The entirety of temporal lobe, parietal lobe, and occipital lobe, are within the **middle fossa**.

The only things that are above the wings, anterior to the cavernous sinus but still in the cranium are within the **anterior fossa**. That would be the **frontal lobes** and the **olfactory bulbs**. There is only one structure of the anterior fossa that allows for an opening from cranium to outside cranium—the **cribriform plate** that permits thousands of axons to reach up from the olfactory epithelium (more on this in special senses).

And here is why many students tolerate anterior, middle, posterior without question. What they are evaluated by (what you will be tested on) is in which fossa and through which hole do each of the cranial nerves exit. And since every cranial nerve exits the cranium anteriorly to where the nerves emerge, you need only know the fossae as they exist as if looking at the front of the cranium from behind.

Only the cribriform plate and olfactory nerves and tracts are in the anterior fossae. All exit in the front. The world of medical education is riddled with a superior view of the base of the cranium, without depth, without any tentorium cerebelli or temporal lobes to show the natural separation of the fossae. So with this fresh perspective in mind, let's talk about these cranial nerves.

The **middle cranial fossa.** The **optic nerve** (CN II) exits through the **optic canal** (well named). The cranial nerves that move the eye—Occulomotor (CN III), Trochlear (CN IV), and Abducens (CN VI) enter the **cavernous sinus** and exit through the **superior orbital fissure** (not quite as good as optic canal, but they are all going into the orbit to innervate the muscles of the eye). The trigeminal nerve trifurcates, sending its **ophthalmic** ($V_1$) and **maxillary** ($V_2$) divisions into the cavernous sinus. The ophthalmic division exits through the **superior orbital fissure** (with the other nerves headed into the orbit), while the maxillary division exits the **foramen rotundum**. The **mandibular division** ($V_3$) does not exit through the cavernous sinus, but rather immediately prior to it through the **foramen ovale**. It is the last of the cranial nerves to exit in the middle cranial fossa.

The **inferior cranial fossae** are where there higher-number, more inferior cranial nerves exit. The pattern is that they go in the direction they emerge. Both the **facial nerve** (CN VII) and the **vestibulocochlear nerve** (CN VIII) emerge on the lateral aspect of the pons. They continue out together through the **auditory meatus**. The next three - glossopharyngeal (CN IX), Vagus (CN X), and CN XI leave through the **jugular foramen**. Last to leave is the lowest cranial nerve, the **hypoglossal** nerve (CN XII).

Again, notice the pattern—higher cranial nerves exit more anterior in the skull. They keep their pattern. The foramina through which the cranial nerves exit is not a difficult concept to understand. But once you no longer have the illustration in front of you, and it's five months from now, all the fossae tend to run together, so most choose to skip this subject. Recognize the pattern, move on. It's more important to know the function and, therefore, dysfunction of the nerves rather than the hole in the skull they leave through.

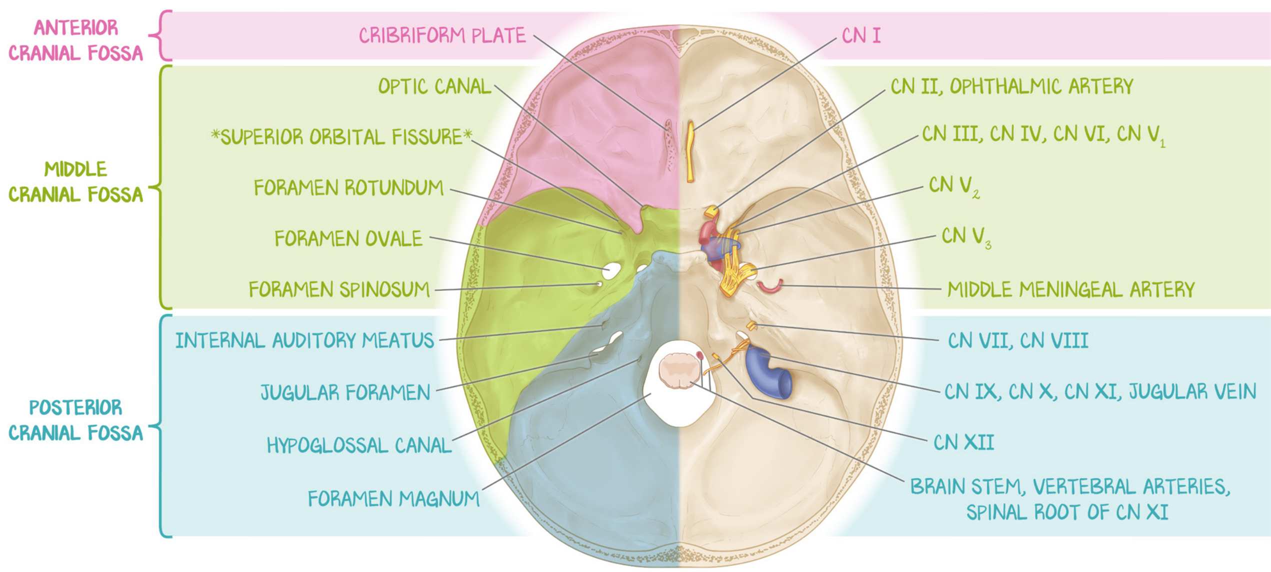


**Figure 5.7: Cranial Fossae and the Cranial Nerves That Use Them**
The cranium is divided into an anterior, middle, and posterior fossa, defined by the sphenoid and petrosal portion of the temporal bone. Anterior to the sphenoid bone is the anterior cranial fossa, where the cribriform plate and the optic bulb are located, on which the frontal lobe sits. The posterior fossa is more of an inferior fossa, and the foramina accessed in the anterior of the 'posterior' fossa are accessed by the lower cranial nerves. CN I exits in the anterior fossa, CN II–V (all three divisions $V_1$, $V_2$, and $V_3$) exit in the middle cranial fossa, and the remainder in the posterior cranial fossa.

What's the ophthalmic division of the trigeminal nerve? Why, we're so glad you asked—let's dive into the details of the **sensory nerve of the face**, the **trigeminal nerve**.

## Trigeminal Nerve

The trigeminal nerve (CN V) is one nerve that branches into three divisions. Remember that trigeminal sensory column in the nuclei map? Remember how much sensory was dedicated to the face in the primary somatosensory cortex? The trigeminal nerve is the nerve that carries all of those sensory fibers. It is a massive nerve that exits on the lateral side of the pons, emanating from the middle cerebellar peduncle. It is a common nerve that almost immediately trifurcates. As it exits the pons, it encounters the temporal lobe and so conforms to the temporal lobe's shape, twisting a little as it does, making that trifurcation into superior, middle, and inferior divisions. The superior is named the **ophthalmic division** (CN $V_1$), the middle is named the **maxillary division** (CN $V_2$), and the inferior is named the **mandibular division** (CN $V_3$). It is also appropriate to call them nerves or branches, rather than divisions. But because no other nerve behaves like this—a trifurcation while within the cranium—and because each division—possessing many of its own branches—innervates a unique, nonoverlapping territory of the face separate from the others, we have chosen to designate the trigeminal nerve's three primary branches, those that arise from the trifurcation, as "divisions."

The **ophthalmic division** is the superior branch. It enters the cavernous sinus lateral and superior to the internal carotid. It exits the cavernous sinus through the **superior orbital fissure** (within the sphenoid bone, next to the oculomotor). This branch has only **cutaneous function**. It does NOT innervate the eye but instead innervates the face of the frontal forehead, eyelids, and top of the nose. It got a bad name because of where it ran in the skull. To fit with the maxillary and mandibular divisions (named for the face bones underlying the skin they innervate), you should think of this as the *"frontal branch"* to match the frontal bone territory (ish, the frontal branch would still be a misnomer, but would not make learners think it had anything to do with the eye).

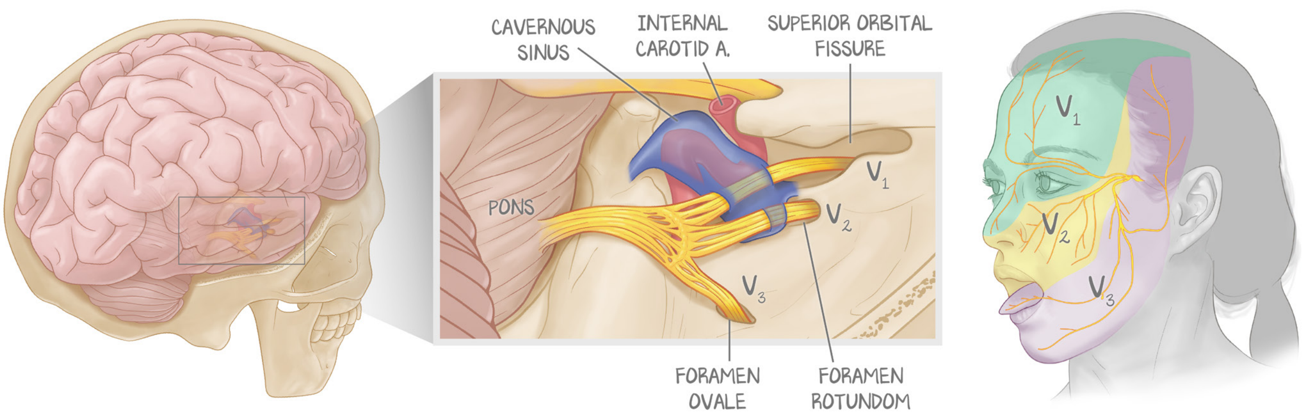


**Figure 5.8: The Trigeminal Nerve**
The trigeminal nerve emerges from the pons and immediately trifurcates into three divisions. The third division, the mandibular division ($V_3$), exits the cranial fossa first, through the foramen ovale, to innervate the lower third of the face and contributes to the lingual nerve (facial nerve fibers carry taste sensation and parasympathetic motor to the salivary glands, the trigeminal nerve handles general touch sensation as well as pain/temperature). The first division, the ophthalmic division ($V_1$), exits last, but also the most anteriorly, first through the cavernous sinus, then through the superior orbital fissure. It innervates the top third of the face—forehead, eyes, and tip of the nose. The second division, the maxillary division ($V_2$), enters the cavernous sinus, exits through the foramen rotundum, and innervates whatever $V_1$ and $V_3$ do not.

The **maxillary division** (CN $V_2$) is the middle branch. It enters the cavernous sinus inferior and lateral to the carotid artery and leaves through the **foramen rotundum**. We intentionally omit a fair stretch of its course through foramina and crossing structures, giving little attention to the complexities that occur in the skull. The trigeminal nerve is a sensory nerve with a little bit of motor; that's it. The maxillary division innervates the skin that the ophthalmic division and the mandibular divisions do not—alar nose, tops of the cheeks.

The **mandibular division** (CN $V_3$) is the inferior branch. It does NOT enter the cavernous sinus but rather leaves through the **foramen ovale**. It innervates the temple, the skin from the temple to the bottom of the jaw, the lower half of the check, and the lower lip. It also is responsible for general touch sensation as well as for pain and temperature on the **anterior two-thirds of the tongue**. In the discussion of the facial nerve, below, we include more details.

Did you see what we did there? There are many branches, many foramina, many terminal nerves that come from this cranial nerve. It is not just a cutaneous nerve of the face. But for you, it is.

 

## Facial Nerve

The facial nerve (CN VII) controls the **muscles of facial expression** and functions in the conveyance of **taste sensation** for the anterior two-thirds of the tongue. Cranial nerve VII technically doesn't emerge as a peripheral nerve of the cranium. It arises as an intermediate nerve, carrying the motor function of the nerve, and meets with another nerve carrying sensory and parasympathetic autonomics. It provides parasympathetic innervation to the parasympathetic ganglia of the head and neck (that would be parasympathetic motor innervation). It goes to the otic ganglion, pterygopalatine ganglia, and others. That's a lot to understand, so we're going with an easier version: it exits as cranial nerve VII and handles motor to the face and salivary glands and taste sensation to the anterior two-thirds of the tongue.

Cranial nerves VII and VIII emerge on the lateral side of the bottom of the pons, VIII more lateral than VII. Together they enter the **internal auditory meatus** (which is a foramen, a hole in the skull). As soon as it enters, it becomes the **geniculate ganglion**. This ganglion (cluster of neurons) contains the cell bodies for the sensory neurons that encode **taste sensation**. Much like the sensory cells of the dorsal root ganglia of the spine, this sensory nerve has its cell body in the ganglion and has a bifurcated axon. It works just like peripheral sensory neurons, except these axons project to the taste center in the CNS (nucleus of the solitary tract, but just learn "taste center").

From the geniculate ganglion, **taste sensation** and **parasympathetic motor** continue as the **chorda tympani**. It meets and merges with the **lingual nerve** (a branch of the mandibular division of the trigeminal nerve, $V_3$). Together within the lingual nerve, axons of sensory neurons of CN VII innervate the anterior two-thirds of the tongue, sensing taste, while axons of sensory neurons of CN $V_3$ innervate the anterior two-thirds of the tongue sensing both general sensation and pain and temperature (the lingual nerve also innervates the mucosa on the inside of the mouth). Axons of first-order parasympathetic neurons (originating in the brainstem) leave the chorda tympani as it merges with the lingual nerve to enter the **submandibular ganglion**. There, they synapse with second-order parasympathetic neurons, which innervate the submandibular and sublingual glands. Even though we want to keep this simple, it's worth pointing out that it was no coincidence that the parasympathetic motor and taste sensation arose as separate nerves initially—they enter and leave CN VII within a very narrow span—whereas CN VII continues on with one mission: skeletal muscle innervation. That was a lot, but that was the small branch from the geniculate ganglion. Back to that ganglion we go!

Now only containing axons from neurons that activate skeletal muscle, CN VII exits the skull through the **stylomastoid foramen**. It exits the skull and gives off the **posterior auricular nerve** ("behind-the-ear nerve") to innervate skeletal muscles behind the ear and the back of the head. The rest of CN VII then **enters but does not innervate the parotid gland**. Within the parotid gland, CN VII branches into five terminal nerves from superior at the forehead and orbit to inferior at the muscles of the neck: temporal, zygomatic, buccal, marginal mandibular, and cervical.

The two most important things to learn about CN VII is that it does not innervate the parotid, but it does exist in the parotid. CN VII can be **easily injured in parotid surgery**.

A common question on licensing exams assesses your knowledge of the motor system. Here are the rules. **Rule one:** a lesion of the facial nerve before the parotid or of the motor nucleus in the brainstem will lead to paralysis of all the facial muscles. Because CN VII is a peripheral nerve of the cranium and carries all of the motor fibers, there will be a lower motor neuron lesion to the forehead, cheeks, and jaw—the whole ipsilateral side of the face. **Rule two:** the vascular territory is not shared between motor, parasympathetics, and taste, so no one brainstem stroke will cause the loss of all three. They are together for such a short distance that it is practically impossible to damage all three at once. **Rule three:** there is bilateral innervation of the motor nucleus—most from the contralateral cortex (just like every other motor tract, these axons decussate at the medulla), and some from the ipsilateral cortex. That means a stroke of the contralateral motor cortex would result in an upper motor neuron lesion of the lower half of the face (as expected) but would demonstrate **sparing of the forehead** because of the ipsilateral innervation of the motor cortex. Very few systems have this sort of dual innervation. It makes teleologic sense to have dual innervation that opens the eyelids because vision is so important to survival (three cranial nerves and the entire occipital lobe are dedicated to vision).

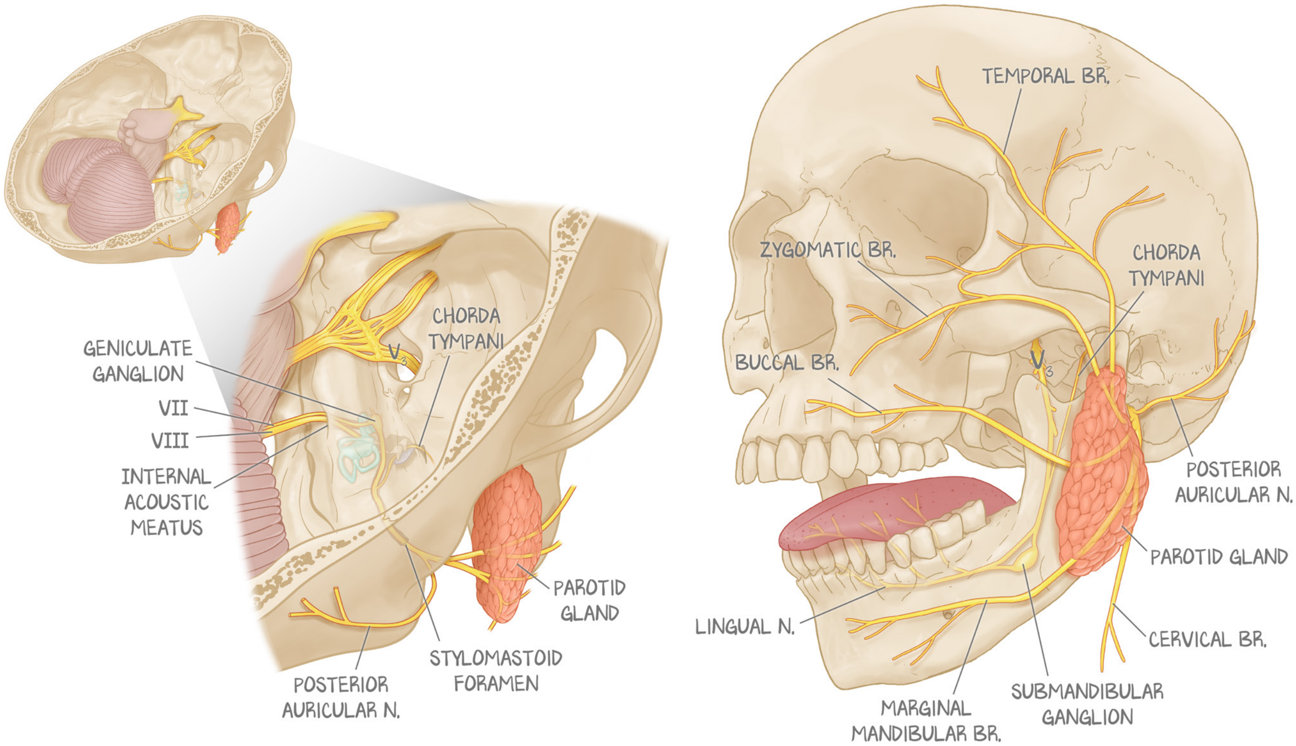


**Figure 5.9: The Facial Nerve**
The course is difficult to follow. It has two motor components—sympathetic to the skeletal muscle of the face, and parasympathetic to the submandibular and sublingual glands—and one sensation component—taste to the anterior two-thirds of the tongue. The facial nerve passes through, but does not innervate, the parotid gland, branching into its many terminal branches within the body of the parotid.